CHAPTER 2

HARDWARE

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

1. Explain the cpu and describe the functions of the different sections.
2. Categorize the types of storage and their functions.
3. Describe how storage is classified.
4. Analyze and compare the input/output devices and explain their functions.

INTRODUCTION

Components or tools of a computer system are grouped into one of two categories, hardware or software. We refer to the machines that compose a computer system as hardware. This hardware includes all the mechanical, electrical, electronic, and magnetic devices within the computer itself (the central processing unit) and all related peripheral devices (printers, magnetic tape units, magnetic disk drive units, and so on). These devices will be covered in this chapter to show you how they function and how they relate to one another. Take a few minutes to study figure 2-1. It shows the functional units of a computer system: the inputs, the central processing unit (cpu), and the outputs. The inputs can be on any storage medium from punched cards, paper tape, or magnetic ink to magnetic tape, disk, or drum; or they can be entries from a console keyboard or a cathode-ray tube (crt) terminal. The data from one or more of these inputs will be processed by the central processing unit to produce output. The output may be in punched cards or paper tape, on magnetic tape, disk, or drum, or it may be printed reports or information displayed on a console typewriter or crt terminal. The figure also shows the data flow, instruction flow, and flow of control. We'll start our hardware discussion with the cpu and then move into storage media (disk, tape, and drum). We'll end the chapter with a discussion of input/output devices and how they work.

CENTRAL PROCESSING UNIT (CPU)

The brain of a computer system is the central processing unit, which we generally refer to as the cpu or mainframe. The central processing unit IS THE COMPUTER. It is the cpu that processes the data transferred to it from one of the various input devices, and then transfers either the intermediate or final results of the processing to one of many output devices. A central control section and work areas are required to perform calculations or manipulate data. The cpu is the computing center of the system. It consists of a control section, internal storage section (main or primary memory), and arithmetic-logic section (fig. 2-1). Each of the sections within the cpu serves a specific function and has a particular relationship to the other sections within the cpu.

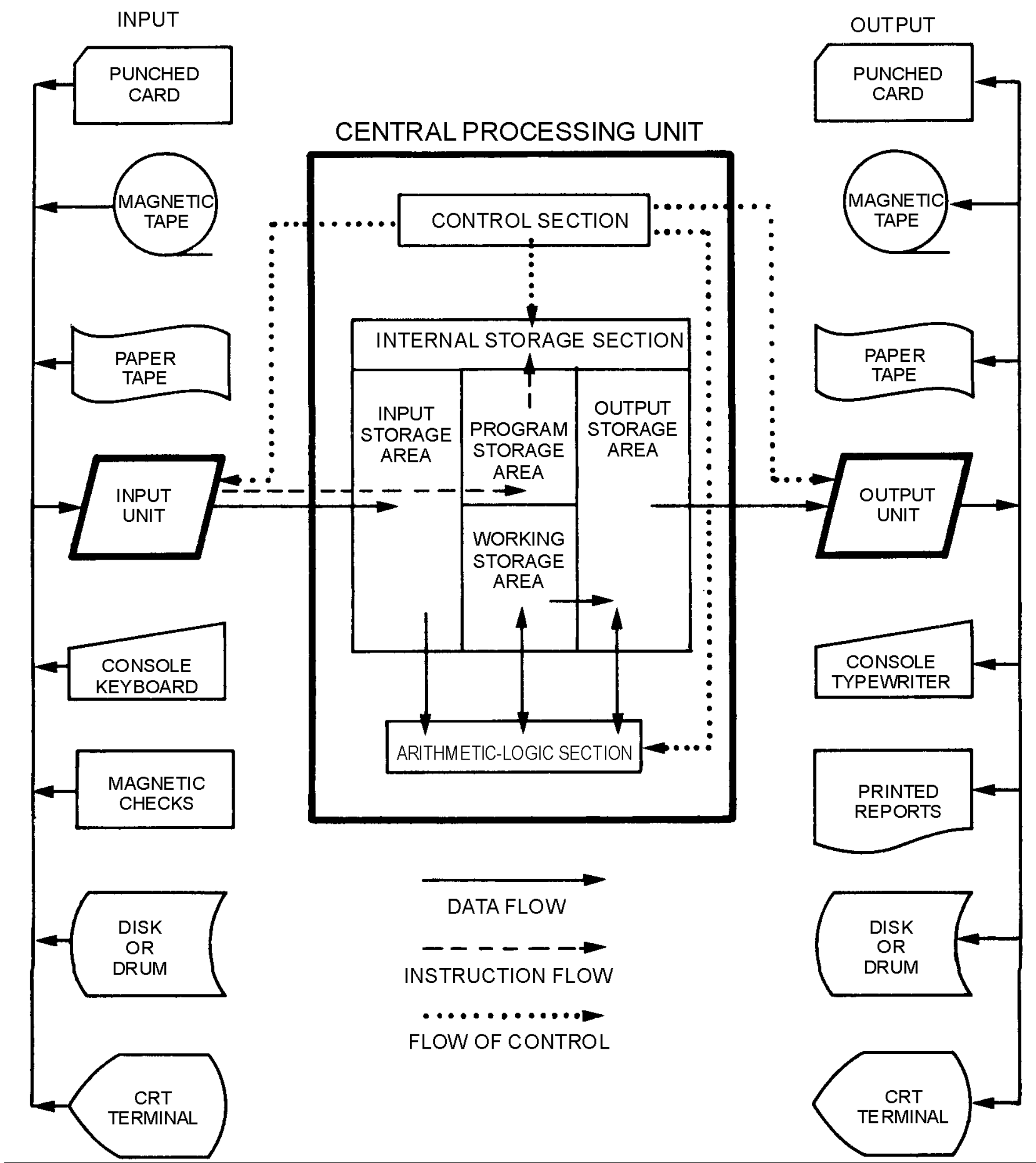

Figure 2-1.—Functional units of a computer system.

CONTROL SECTION

The control section may be compared to a telephone exchange because it uses the instructions contained in the program in much the same manner as the telephone exchange uses telephone numbers. When a telephone number is dialed, it causes the telephone exchange to energize certain switches and control lines to connect the dialing phone with the phone having the number dialed. In a similar manner, each programmed instruction, when executed, causes the control section to energize certain control lines, enabling the computer to perform the function or operation indicated by the instruction.

The program may be stored in the internal circuits of the computer (computer memory), or it may be read instruction-by-instruction from external media. The internally stored program type of computer, generally referred to only as a stored-program computer, is the most practical type to use when speed and fully automatic operation are desired.

Computer programs may be so complex that the number of instructions plus the parameters necessary for program execution will exceed the memory capacity of a stored-program computer. When this occurs, the program may be sectionalized; that is, broken down into modules. One or more modules are then stored in computer memory and the rest in an easily accessible auxiliary memory. Then as each module is executed producing the desired results, it is swapped out of internal memory and the next succeeding module read in.

In addition to the commands that tell the computer what to do, the control unit also dictates how and when each specific operation is to be performed. It is also active in initiating circuits that locate any information stored within the computer or in an auxiliary storage device and in moving this information to the point where the actual manipulation or modification is to be accomplished.

The four major types of instructions are (1) transfer, (2) arithmetic, (3) logic, and (4) control. Transfer instructions are those whose basic function is to transfer (move) data from one location to another. Arithmetic instructions are those that combine two pieces of data to form a single piece of data using one of the arithmetic operations.

Logic instructions transform the digital computer into a system that is more than a high-speed adding machine. Using logic instructions, the programmer may construct a program with any number of alternate sequences. For example, through the use of logic instructions, a computer being used for maintenance inventory will have one sequence to follow if the number of a given item on hand is greater than the order amount and another sequence if it is smaller. The choice of which sequence to use will be made by the control section under the influence of the logic instruction. Logic instructions, thereby, provide the computer with the ability to make decisions based on the results of previously generated data. That is, the logic instructions permit the computer to select the proper program sequence to be executed from among the alternatives provided by the programmer.

Control instructions are used to send commands to devices not under direct command of the control section, such as input/output units or devices.

ARITHMETIC-LOGIC SECTION

The arithmetic-logic section performs all arithmetic operations-adding, subtracting, multiplying, and dividing. Through its logic capability, it tests various conditions encountered during processing and takes action based on the result. As indicated by the solid arrows in figure 2-1, data flows between the arithmetic-logic section and the internal storage section during processing. Specifically, data is transferred as needed from the internal storage section to the arithmetic-logic section, processed, and returned to the internal storage section. At no time does processing take place in the storage section. Data may be transferred back and forth between these two sections several times before processing is completed. The results are then transferred from internal storage to an output unit, as indicated by the solid arrow (fig. 2-1).

MEMORY (INTERNAL STORAGE) SECTION

All memory (internal storage) sections must contain facilities to store computer data or instructions (that are intelligible to the computer) until these instructions or data are needed in the performance of the computer calculations. Before the stored-program computer can begin to process input data, it is first necessary to store in its memory a sequence of instructions, and tables of constants and other data it will use in its computations. The process by which these instructions and data are read into the computer is called loading.

Actually, the first step in loading instructions and data into a computer is to manually place enough instructions into memory using the keyboard or electronically using an operating system (discussed in chapter 1), so that these instructions can be used to bring in more instructions as desired. In this manner a few instructions are used to bootstrap more instructions. Some computers make use of an auxiliary (wired) memory that permanently stores the bootstrap program, thereby making manual loading unnecessary.

The memory (internal storage) section of a computer is essentially an electronically operated file cabinet. It has a large number (usually several hundred thousand) of storage locations; each referred to as a storage address or register. Every item of data and program instruction read into the computer during the loading process is stored or filed in a specific storage address and is almost instantly accessible.

Q-1. What is the brain of a computer system?

Q-2. How many sections make up the central processing unit?

Q-3. What are the names of the sections that make up the cpu?

Q-4. The control section can be compared to what?

Q-5. What are the four major types of instructions in the control section?

Q-6. What capability allows the arithmetic/logic section to test various conditions encountered during processing and take action based on the result?

Q-7. In the arithmetic/logic section, data is returned to what section after processing?

Q-8. What is the process by which instructions and data are read into a computer?

TYPES OF INTERNAL STORAGE

You already know that the internal storage section is the holding area in which instructions and data are kept. For the control section to control and coordinate all processing activity, it must be able to locate each instruction and data item in storage. About now, you are probably wondering how the control section is able to find these instructions and data items. To understand this, let's look at storage as nothing more than a collection of mailboxes. Each mailbox has a unique address and represents a location in memory as shown in figure 2-2. Like the mail in your mailbox, the contents of a storage location can change, but the number on your mailbox or memory address always remains the same. In this manner, a particular program instruction or data item that is held in storage can be located by knowing its address. Some computers can address each character of data in memory directly. Others address computer words which contain a group of characters at a single address. Each computer word contains a group of characters at a single address. Some of the more common types of internal storage media used in today's computers are as follows: magnetic core, semiconductor, and bubble.

PRIMARY STORAGE

1001	1002	39 29 1003	1004	1005
1006	1007	1008	86 48 1009	1010

Figure 2-2.—Memory locations.

MAGNETIC CORE STORAGE

Although magnetic core storage is no longer as popular as it once was, we will cover it in some detail because its concepts are easily understood and apply generally to the more integrated semiconductor and bubble-type memories. Magnetic core storage is made up of tiny doughnut-shaped rings made of ferrite (iron), that are strung on a grid of very thin wires (fig. 2-3). Since data in computers is stored in binary form (refer to *NEETS*, module 13), a two-state device is needed to represent the two binary digits (bits), 0 for off and 1 for on. In core storage, each ferrite ring can represent a 0 or 1 bit, depending on its magnetic state. If magnetized in one direction, it represents a 1 bit, and if magnetized in the opposite direction, it represents a 0 bit. These cores are magnetized by sending an electric current through the wires on which the core is strung. It is this direction of current that determines the state of each core.

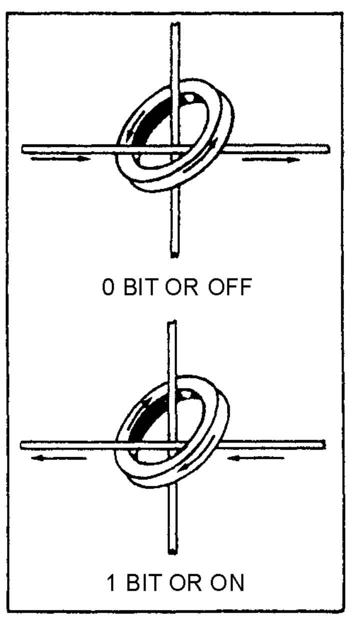

Figure 2-3.—Two-state principle of magnetic storage.

SEMICONDUCTOR STORAGE (THE SILICON CHIP)

Semiconductor memory consists of hundreds of thousands of tiny electronic circuits etched on a silicon chip (fig. 2-4). Each of these electronic circuits is called a bit cell and can be in either an off or on state to represent a 0 or 1 bit, depending on whether or not current is flowing in that cell. Another name you will hear used for semiconductor memory chips is integrated circuits (ICs). Developments in technology have led to large scale integration (LSI), which means that more and more circuits can be squeezed onto the same silicon chip. Companies are even manufacturing very large scale integrated circuits (VLSI), which means even further miniaturization.

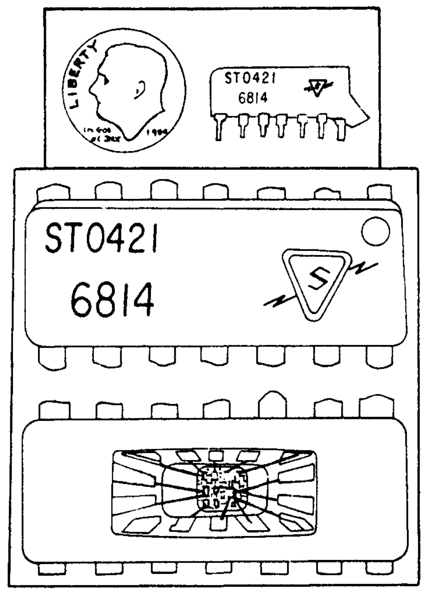

Figure 2-4.—A semiconductor memory chip (integrated circuit).

Some of the advantages of semiconductor storage are fast internal processing speeds, high reliability, low power consumption, high density (many circuits), and low cost. However, there is a drawback to this type of storage. It is volatile, which means all data in memory is lost when the power supply is removed. Should the power on your computer fail and you have no backup power supply, all the stored data is lost. This is not the case with magnetic core storage. Core storage is nonvolatile. This means the data is retained even if there is a power failure or breakdown, since the cores store data in the form of magnetic charges rather than electric current.

BUBBLE STORAGE

One of the latest technological developments in storage media is the introduction of bubble memory. Bubble memory consists of a very thin crystal made of semiconductor material. The molecules of this special crystal act as tiny magnets (fig. 2-5). The polarity of these molecules or "magnetic domains" can be switched in an opposite direction by passing a current through a control circuit imprinted on top of the crystal. In this manner, data can be stored by changing the polarity of the magnetic domains. Since the principle is the same as for magnetic core storage, bubble memory is considered nonvolatile. The data is retained even if there is a power failure. Furthermore, the process of reading from bubble memory is nondestructive, meaning that the data is still present after being read. This is not the case with core storage, which must be regenerated after being read. If we were to view these magnetic domains under a microscope, they would look like tiny bubbles; hence the name, bubble memory.

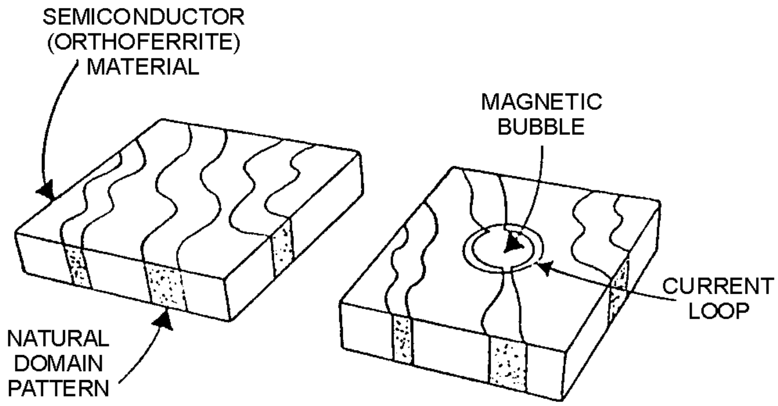

Figure 2-5.—Bubble memory.

Q-9. Magnetic core storage is made up of what?

Q-10. A semiconductor memory consists of what?

Q-11. What is another name for semiconductor memory chips?

Q-12. In computer storage, what does volatile mean?

Q-13. What type of storage can retain its data even if there is a power failure or breakdown?

Q-14. Bubble memory consists of what?

Q-15. How are the magnetic domains of a bubble memory switched?

Q-16. What do we mean when we say that reading from bubble memory is nondestructive?

CLASSIFICATIONS OF INTERNAL STORAGE

Up to this point, you have learned some of the general functions of the cpu, the physical characteristics of memory, and how data is stored in the internal storage section. Now, we will explain yet another way to classify internal (primary or main) storage. This is by the different kinds of memories used within the cpu: read-only memory, random-access memory, programmable read-only memory, and erasable programmable read-only memory.

READ-ONLY MEMORY (ROM)

In most computers, it is useful to have often used instructions, such as those used to bootstrap (initial system load) the computer or other specialized programs, permanently stored inside the computer. Memory that enables us to do this without the programs and data being lost (even when the computer is powered down) is called read-only memory. Only the computer manufacturer can provide these programs in ROM and once done, they cannot be changed. Consequently, you cannot put any of your own data or programs in ROM. Many complex functions such as routines to extract square roots, translators for programming languages, and operating systems can be placed in ROM memory. Since these instructions are hard wired (permanent), they can be performed quickly and accurately. Another advantage of ROM is that your computer facility can order programs tailored for its needs and have them permanently installed in ROM by the manufacturer. Such programs are called microprograms or firmware.

RANDOM-ACCESS MEMORY (RAM)

Another kind of memory used inside computers is called random-access memory (RAM) or read/write memory. RAM memory is rather like a blackboard on which you can scribble down notes, read them, and rub them out when you are finished with them. In the computer, RAM is the working memory. Data can be read (retrieved) from or written (stored) into RAM just by giving the computer the address of the location where the data is stored or is to be stored. When the data is no longer needed, you can simply write over it. This allows you to use the storage again for something else. Core, semiconductor, and bubble storage all have random access capabilities.

PROGRAMMABLE READ-ONLY MEMORY (PROM)

An alternative to ROM is programmable read only memory (PROM) that can be purchased already programmed by the manufacturer or in a blank state. By using a blank PROM, you can enter any program into the memory. However, once the PROM has been written into, it can never be altered or changed. Thus you have the advantage of ROM with the additional flexibility to program the memory to meet a unique need. The main disadvantage of PROM is that if a mistake is made and entered into PROM, it cannot be corrected or erased. Also, a special device is needed to "burn" the program into PROM.

ERASABLE PROGRAMMABLE READ-ONLY MEMORY (EPROM)

The erasable programmable read-only memory (EPROM) was developed to overcome the drawback of PROM. EPROMs can also be purchased blank from the manufacturer and programmed locally at your command/activity. Again, this requires special equipment. The big difference with EPROM is that it can be erased if and when the need arises. Data and programs can be retrieved over and over again without destroying the contents of the EPROM. They will stay there quite safely until you want to reprogram it by first erasing the EPROM with a burst of ultra-violet light. This is to your advantage, because if a mistake is made while programming the EPROM, it is not considered fatal. The EPROM can be erased and corrected. Also, it allows you the flexibility to change programs to include improvements or modifications in the future.

Q-17. In what type of memory are often used instructions and programs permanently stored inside the computer?

Q-18. Who provides the programs stored in ROM?

Q-19. Can programs in ROM be changed?

Q-20. What is another name for random-access memory (RAM)?

Q-21. How is data read from or written into RAM?

Q-22. In what two states can programmable read-only memory (PROM) be purchased?

Q-23. What is the main disadvantage of PROM?

Q-24. What does EPROM stand for?

Q-25. How is EPROM erased?

SECONDARY STORAGE

The last kind of memory we will briefly introduce here is called secondary storage or auxiliary storage. This is memory outside the main body of the computer (cpu) where we store programs and data for future use. When the computer is ready to use these programs and data, they are read into internal storage. Secondary (auxiliary) storage media extends the storage capabilities of the computer system. We need it for two reasons. First, because the computer's internal storage is limited in size, it cannot always hold all the data we need. Second, in secondary storage, data and programs do not disappear when power is turned off. Secondary storage is nonvolatile. This means information is lost only if you, the user, intentionally erase it. The three types of secondary storage we most commonly use are magnetic disk, tape, and drum.

MAGNETIC DISK

The popularity of disk storage devices is largely because of their direct-access capabilities. Most every system (micro, mini, and mainframe) will have disk capability. Magnetic disks resemble phonograph records (round platters), coated with a magnetizable recording material (iron oxide), but their similarities end there. Magnetic disks come in many different sizes and storage capacities. They range from 3 inches to 4 feet in diameter and can store from 2.5 million to 600 million characters (bytes) of data. They can be portable in that they are removable, or they can be permanently mounted in the storage devices called disk drive units or disk drives. They can be made of rigid metal (hard disks) or flexible plastic (floppy disks or diskettes) as shown in figure 2-6.

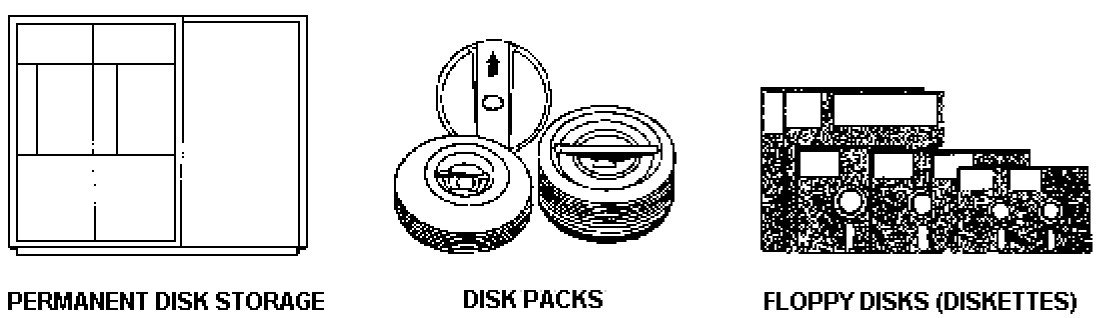

Figure 2-6.—Various types and sizes of magnetic disk storage.

Music is stored on a phonograph record in a continuous groove that spirals into the center of the record. But there are no grooves on a magnetic disk. Instead, data is stored on all disks in a number of invisible concentric circles called tracks. Each track has a designated number beginning with track 000 at the outer edge of the disk. The numbering continues sequentially toward the center to track 199, 800, or whatever the highest track number is. No track ever touches another (fig. 2-7). The number of tracks can vary from 35 to 77 on a floppy disk surface and from 200 to over 800 on hard disk surfaces.

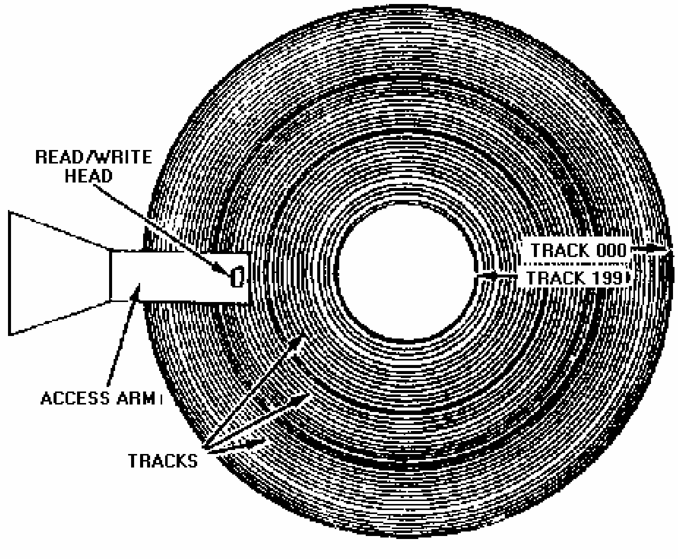

Figure 2-7.—Location of tracks on the disk's recording surface.

Data is written as tiny magnetic bits (or spots) on the disk surface. Eight-bit codes are generally used to represent data. Each code represents a different number, letter, or special character. In chapter 4, you'll learn how the codes are formed. When data is read from the disk, the data on the disk remains unchanged. When data is written on the disk, it replaces any data previously stored on the same area of the disk.

Characters are stored on a single track as strings of magnetized bits (0's and 1's) as shown in figure 2-8. The 1 bits indicate magnetized spots or ON bits. The 0 bits represent unmagnetized portions of the track or OFF bits. Although the tracks get smaller as they get closer to the center of the disk platter, each track can hold the same amount of data because the data density is greater on tracks near the center.

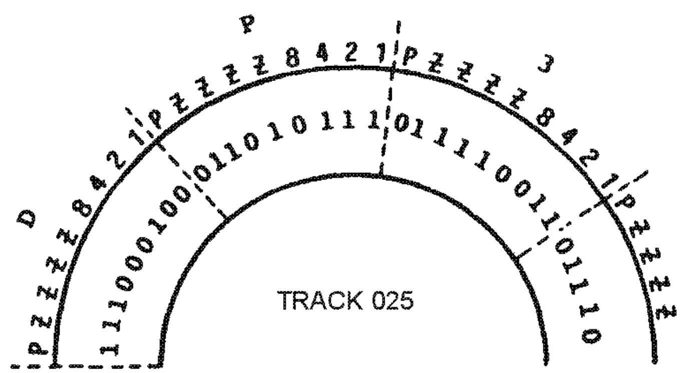

Figure 2-8.—A string of bits written to disk on a single track.

A track can hold one or more records. A record is a set of related data treated as a unit. The records on a track are separated by gaps in which no data is recorded, and each of the records is preceded by a disk address. This address indicates the unique position of the record on the track and is used to directly access the record. Figure 2-9 shows a track on which five records have been recorded. Because of the gaps and addresses, the amount of data we can store on a track is reduced as the number of records per track is increased. Records on disk can be blocked (grouped together). Only one disk address is needed per block, and as a result, fewer gaps occur. We can use the blocking technique to increase the amount of data we can store on one track.

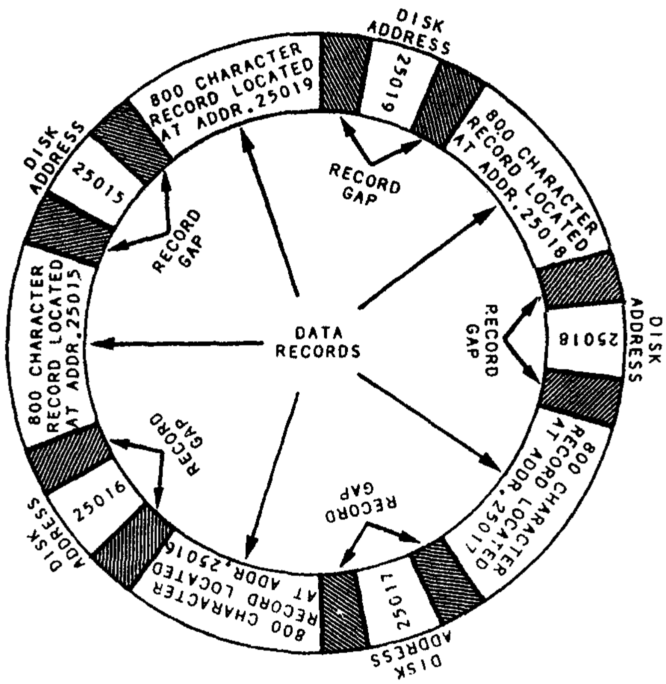

Figure 2-9.—Data records as they are written to disk on a single track.

The storage capacity of a disk depends on the bits per inch of track and the tracks per inch of surface. Using Winchester technology, the designers of disk drive units were able to increase the data density of a disk by increasing the number of tracks. Winchester was the code name used by IBM during the development of this technology. The designers originally planned to use dual disk drives to introduce the new concept. Each drive was to have a storage capacity of 30 million characters, and thus was expected to be a "30-30." Since that was the caliber of a famous rifle, the new product was nicknamed "Winchester." The designers found that data density could be improved and storage capacity increased by reducing the flying height, the distance of the read/write heads over the disk surfaces when reading and writing. By doing this, smaller magnetized spots could be precisely written and then read. The read/write heads were moved so close to the disk that a human hair looked like a mountain in the path of the flying head. Winchester technology reduces this potential problem by sealing the disks in a contamination-free container. This eliminates foreign objects from coming in contact with the read/write heads.

Data can be physically organized in one of two ways on a disk pack, depending on the manufacturer and the model of disk drive you are using. One way uses the cylinder method, and the other uses the sector method. On diskettes, data is organized using the sector method.

The cylinder method uses a cylinder as the basic reference point. When you look at figure 2-10, view A, you will see a disk pack containing six disk platters with 10 recording surfaces. Imagine you are looking down through the disk pack from the top. All the tracks with the same number line up vertically. Together they are called a cylinder. These 10 tracks, one on each recording surface, can be referenced by the 10 read/write heads on the five access arms at each discrete location where the access arms can be positioned.

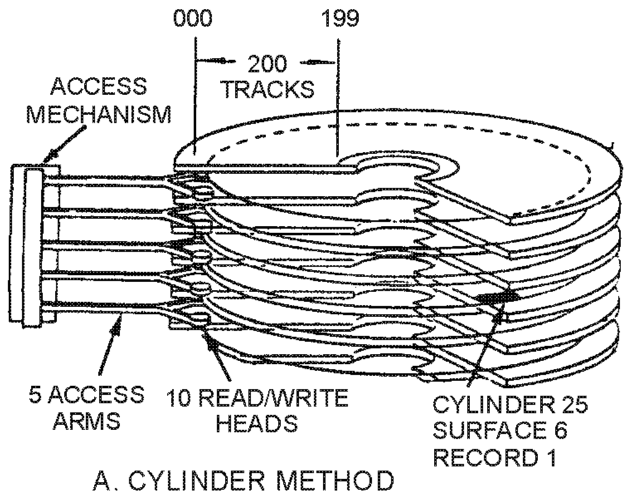

Figure 2-10A.—Physical organization of data on a disk. CYLINDER METHOD.

Therefore, to physically reference a record stored using the cylinder method, a computer program must specify the cylinder number, the recording surface number, and the record number as shown in figure 2-10, view A. Here, the record is stored in cylinder 25 of recording surface 6 and is the first record on that track. Special data stored on each track specifies the beginning of the track so that the first record, second record, third record, and so on, can be identified.

Another way to physically organize data on the disk pack (and on diskettes) is to use the sector method. This requires that each of the tracks be divided into individual storage areas called sectors (shown in figure 2-10, view B). The number of sectors varies with the disk system used; however, there are usually eight or more. Each sector holds a specific number of characters. Before a record can be accessed, a computer program must again give the disk drive the record's address specifying the track number, the surface number, and the sector number of the record. One or more read/write heads are then moved to the proper track, the head over the specified surface is activated, and the data is read from or written to the designated sector as it spins under the head.

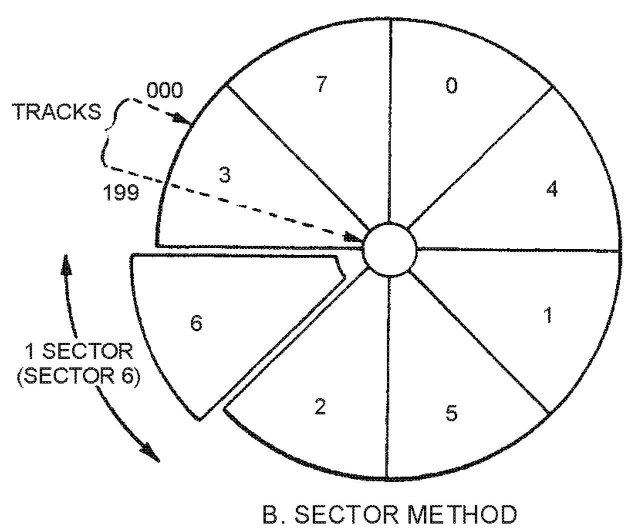

Figure 2-10B.—Physical organization of data on a disk. SECTOR METHOD.

MAGNETIC TAPE

Another type of storage device is magnetic tape which is similar to the tape used with commercial tape recorders. It is used mainly for secondary storage. It differs from commercial tape in that it is usually wider (ranging from one-half inch to an inch), and it is manufactured to more rigid quality specifications. It is made of a MYLAR® base coated with a magnetic oxide that can be magnetized to store data. Magnetic tape comes in a variety of lengths (from 600 to 3,000 feet), and is packaged in one of three ways: open reel, cartridge, or cassette, as shown in figure 2-11. Large computers use standard open reels, 1/2-inch wide tape, 2,400 feet in length. Magnetic tape units are categorized by the type of packaging used for the tape. The tape unit (or drive) shown in figure 2-12 uses open reels, while cartridge tape units use tape cartridges and cassette units use tape cassettes. Cartridge tape units are often used on personal computers to provide backup for hard disk.

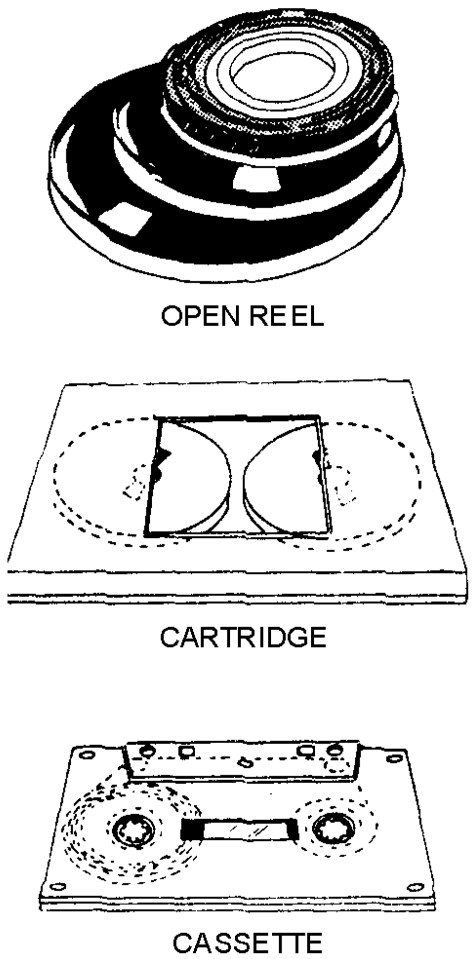

Figure 2-11.—Various types of magnetic tape storage.

Figure 2-12.—Mounting a magnetic tape

A standard 1/2-inch tape may have either seven (fig. 2-13, view A) or nine tracks (fig. 2-13, view B) of data stored on it, depending upon the particular read/write heads installed in the tape unit. Read/write heads are usually designed to read (or write) data (in the form of bits) concurrently across the width of the tape.

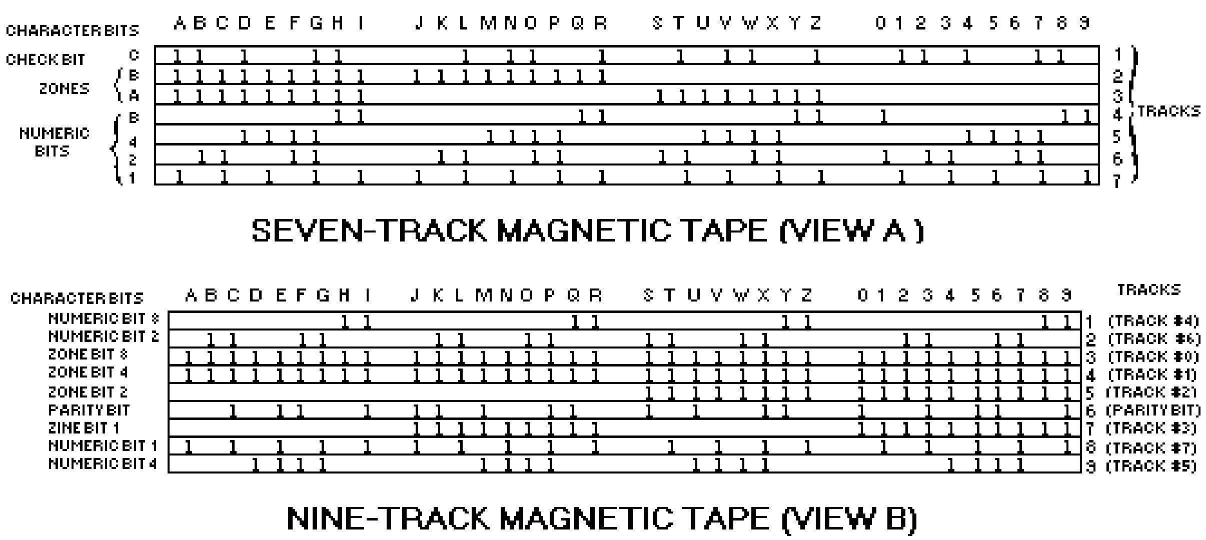

Figure 2-13.—Multi-track magnetic tape.

The amount of data or the number of binary digits (0 and 1 bits) that can be written (stored) on a linear inch of tape is known as the tape's recording density. Common recording densities for multitrack tapes range from 200 to 6,250 bits/bytes per inch (BPI). Also note that sometimes the density of a tape is referred to as the number of frames per inch (FPI) or characters per inch (CPI) rather than BPI. Regardless of which term is used, a frame or byte is a group of related bits that make up a single character written across the width of the tape. Most magnetic tape units are capable of reading and writing in several different densities.

Magnetic tapes have many common features and data recording formats. Each tape is physically marked in some manner to indicate where reading and writing on tape is to begin (known as the beginning-of-tape [BOT]), and where it ends (known as the end-of-tape [EOT]). The length of tape between the BOT and EOT is referred to as the usable recording (reading/writing) surface or usable storage area. BOT/EOT markers are usually made of short silver strips of reflective tape (1/4-inch wide by 1/2-inch long) as shown in figure 2-14. The BOT marker is normally placed toward the front edge of the tape (the side nearest you when the tape is mounted on the tape unit). The EOT marker is placed toward the back edge (the side farthest from you when the tape is mounted on the tape unit). They are placed approximately 15 to 20 feet in from each end on the shiny side of the tape. Sometimes, holes or clear plastic inserts are used as markers in place of reflective strips. Regardless of the method used, the BOT/EOT markers are sensed by an arrangement of lamps and/or photodiode sensors to indicate where reading and writing is to begin and end.

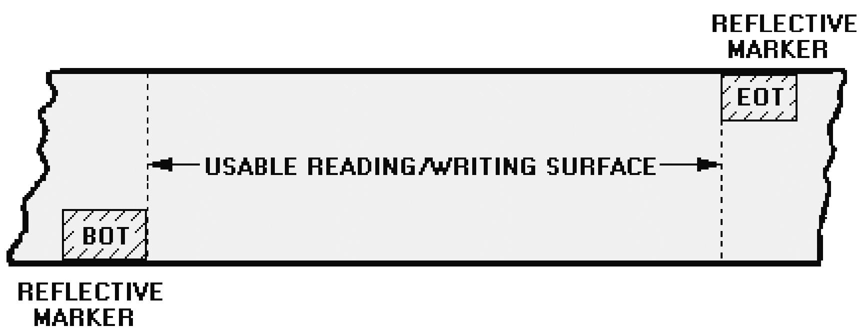

Figure 2-14.—Beginning-of-tape (BOT) and end-of-tape (EOT) markers.

We can make records on magnetic tape any size we need to hold the data. We are restricted only by the length of the tape or the capacity of internal storage. For example, a record can be one character, several characters, or thousands of characters in length. The collection of records is called a file. A file containing payroll records is called a payroll file; a file containing supply inventory records is called a supply inventory file.

Records can be placed on tape either separately as single records (unblocked) as shown in figure 2-15, view A, or multiple records can be grouped together (blocked) as shown in figure 2-15, view B, to form a record block. The number of records stored in a record block is the blocking factor. In this example, the blocking factor is five.

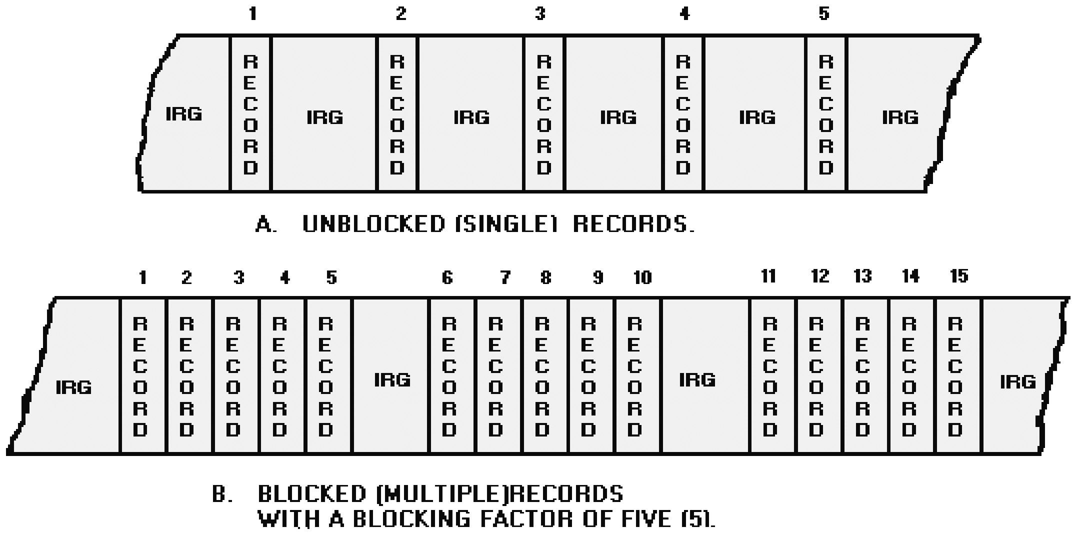

Figure 2-15.—Record formats on magnetic tape.

All magnetic tape must be moving at a predetermined speed for data to be read from or written on the tape. Data cannot be read or written while the tape is coming up to speed, slowing down, or stopped. During this time delay, the tape moves a short distance creating a blank spot on the tape. This interrecord gap or interblock gap separates each single record or block of records on the tape. The length of the gap varies, depending upon the particular system and method of recording, but is approximately 2/5 to 3/4 inch in length. If single records are stored on the tape, the interrecord gap may be longer than the portion of tape used to store the record. Therefore, much of the tape's recording surface is wasted.

To overcome the inefficiency of storing single data records, we normally block records. In figure 2-15, view B, you will notice the tape is used more efficiently than the tape in figure 2-15, view A. Blocking allows more data to be stored on a reel of tape.

During reading, the record begins with the first character sensed following an interrecord or interblock gap and continues until the next gap is reached. All input records read are internally stored in accordance with the amount of storage area set aside by the applications program.

Magnetic tape, as a storage media, offers several useful features. We can store large amounts of data in a variety of convenient package sizes (open reels, cartridges, or cassettes). Magnetic tapes are easily interchangeable between similar tape units of different computer systems, and tapes are less prone to damage than other types of storage media.

MAGNETIC DRUM

Like the magnetic disk, the magnetic drum is another example of a direct-access storage device. Although the magnetic drum was once used as main (or primary) storage, it is now used as secondary (or auxiliary) storage. Unlike some disk packs, the magnetic drum cannot be physically removed. The drum is permanently mounted in the device.

Magnetic drum storage devices consist of either a hollow cylinder (thus, the name drum) or a solid cylinder that rotates at a constant velocity (from 600 to 6,000 rpm). The outer surface is coated with an iron-oxide material capable of being magnetized.

A magnetic drum differs from a magnetic disk in that the tracks in which the data is stored are assigned to channels located around the circumference of the drum as shown in figure 2-16. That is, the channels form circular bands around the drum. The coded representation of data in figure 2-16 is similar to that used on 9-track magnetic tape, 8-bit code. The basic functions of the read/write heads are to place magnetized spots (those little binary 0's and 1's) on the drum during a writing operation and to sense these spots during a reading operation. The read/write heads of a drum perform in a manner similar to the read/write heads of a magnetic tape unit or disk drive unit.

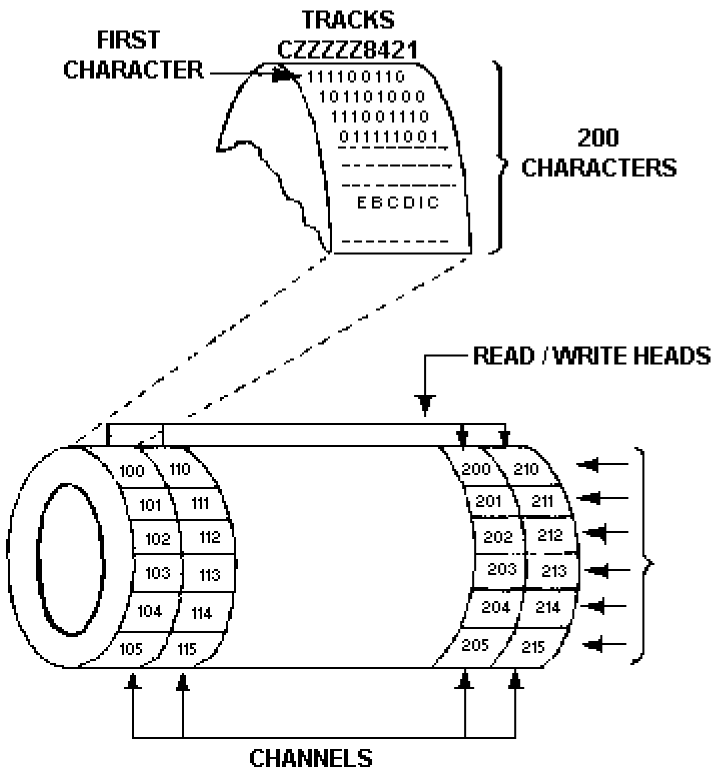

Figure 2-16.—Magnetic drum.

The tracks on each channel are grouped into sectors as illustrated in figure 2-16. Does this sound familiar to you? It sounds almost like the format used on disk packs when referring to tracks (or cylinders) and sectors. As the drum rotates, the reading or writing occurs when the specified sector of a given channel passes under the read/write head for that channel.

Some drums are mounted in a horizontal position, such as the one shown in figure 2-16, while others are mounted in a vertical position. Another major difference in the design is the number of read/write heads. Some drums use only one read/write head, which services all channels on the drum. In this case, the head moves back and forth (or up and down) over the surface of the drum as required. Other drums, using multiple read/write heads, have one principal advantage over drums with the single-head type. Since one read/write head is assigned to each channel, no read/write head movement is required. That is, the time required for head positioning is zero. The only significant time required when reading or writing is the rotational delay that occurs in reaching a desired record location.

To give you some idea of speed and storage capacities, some high-speed drums are capable of transferring over one million characters of data per second, which is roughly equivalent to reading a stack of punched cards 8 feet high in one second. The storage capacities of magnetic drums range from 20 million to more than 150,000 million characters (or bytes) of data.

Q-26. Why are disk storage devices popular?

Q-27. How is data stored on all disks?

Q-28. What precedes each record on a disk?

Q-29. How is the storage capacity of a disk determined?

Q-30. What two ways can data be physically organized on a disk pack?

Q-31. The amount of data that can be stored on a linear inch of tape is known by what term?

Q-32. The length of tape between BOT and EOT is referred to by what term?

Q-33. How does a magnetic drum differ from a magnetic disk?

Q-34. Tracks on each channel of a magnetic drum are grouped into what?

INPUT/OUTPUT DEVICES (EXTERNAL)

Input and output devices are similar in operation but perform opposite functions. It is through the use of these devices that the computer is able to communicate with the outside world. Input data may be in any one of three forms:

1. Manual inputs from a keyboard or console
2. Analog inputs from instruments or sensors
3. Inputs from a source on or in which data has previously been stored in a form intelligible to the computer

Computers can process hundreds of thousands of computer words or characters per second. Thus, a study of the first method (manual input) reflects the inability of human-operated keyboards or keypunches to supply data at a speed that matches the speed of digital computers. A high average speed for keyboard operation is two or three characters per second, that, when coded to form computer words, would reduce the data input rate to the computer to less than a computer word per second. Since mainframe computers are capable of reading several thousand times this amount of information per second, it is clear that manual inputs should be minimized to make more efficient use of computer time. However, as a rule, the keyboard is the normal input media for microcomputers.

Input data that has previously been recorded on paper tapes, magnetic tapes, magnetic disks, or floppy disks in a form understood by the program may also be entered into the computer. These are much faster methods than entering data manually from a keyboard. The most commonly used input devices in this category are magnetic tape units, magnetic disk drive units, and floppy disk drive units.

Output information is also made available in three forms:

1. Displayed information: codes, numbers, words, or symbols presented on a display device like a cathode-ray screen

2. Control signals: information that operates a control device, such as a lever, aileron, or actuator

3. Recordings: information that is stored in a machine language or human language on tapes, disks, or printed media

Devices that display, store, or read information include magnetic tape units, magnetic disk drive units, floppy disk drive units, printers, and display devices.

MAGNETIC TAPE UNITS (INPUT/OUTPUT)

The purpose of any magnetic tape unit (drive or device) is to write data on or read data from a magnetic tape (fig. 2-17). Tape stores data in a sequential manner. In sequential processing, the computer must begin searching at the beginning and check each record until the desired data is found. Like a tape cassette with recorded music, to play the fifth song recorded, you must play or fast forward the tape past the first four songs before you can play the fifth.

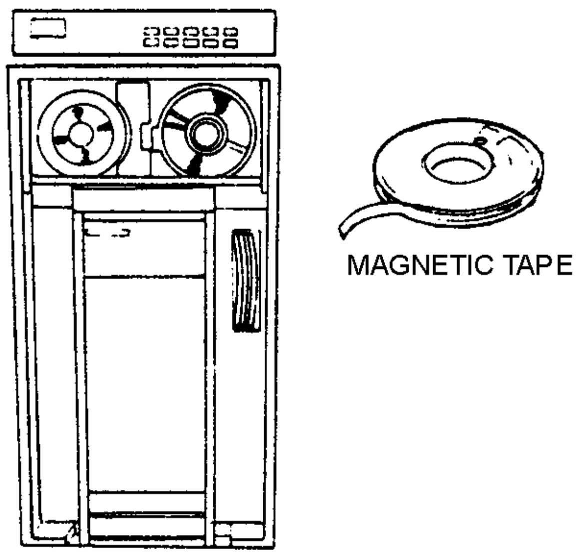

Figure 2-17.—Magnetic tape unit.

Two reels are used, tape moves from a supply reel to a take-up reel (both are mounted on hubs). Figure 2-18 shows the basic tape drive mechanism. The magnetic oxide coated side of the tape passes directly over the read/write head assembly, making contact with the heads. The magnetic tape unit reads and writes data in parallel channels or tracks along the length of the tape as shown in figure 2-19, view A. Each channel or track is used by a read/write head (one for each channel), as the tape moves across the magnetic gap of the head. Read/write heads may be either one gap or two gap as shown in figure 2-19, views B and C. The one-gap head has only one magnetic gap at which both reading and writing occur. The two-gap head has one gap for reading and another for writing. Although the one gap is satisfactory, the two-gap head gives increased speed by checking while writing. For example, a tape being written on passes over the write gap where the data is recorded, and then the data is read as it passes over the read gap to make a comparison. With this method, errors are detected almost instantly. When you look closely at figure 2-19, view B (top view), you will notice that there is one read/write coil in the write head for each channel (or track). In this particular case, there are seven. It is the electrical current flowing through these coils that magnetizes the iron-oxide coating on the surface of the tape.

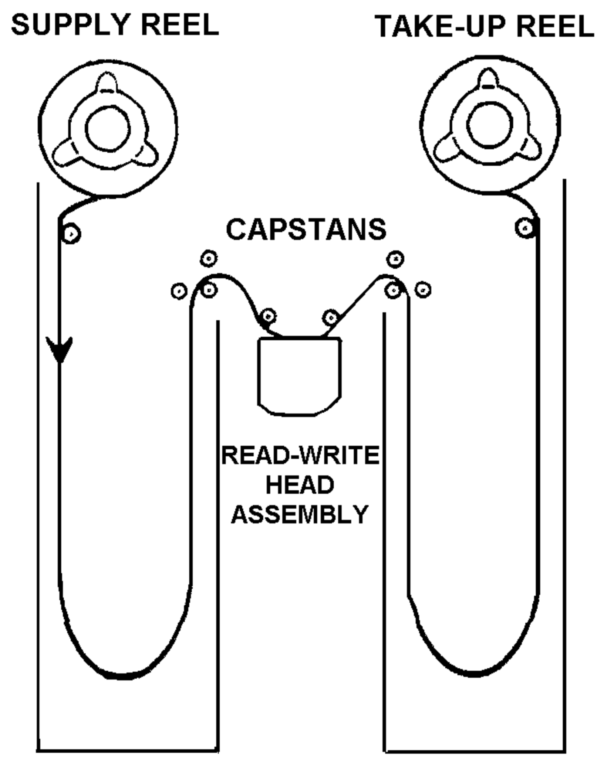

Figure 2-18.—A basic tape drive mechanism.

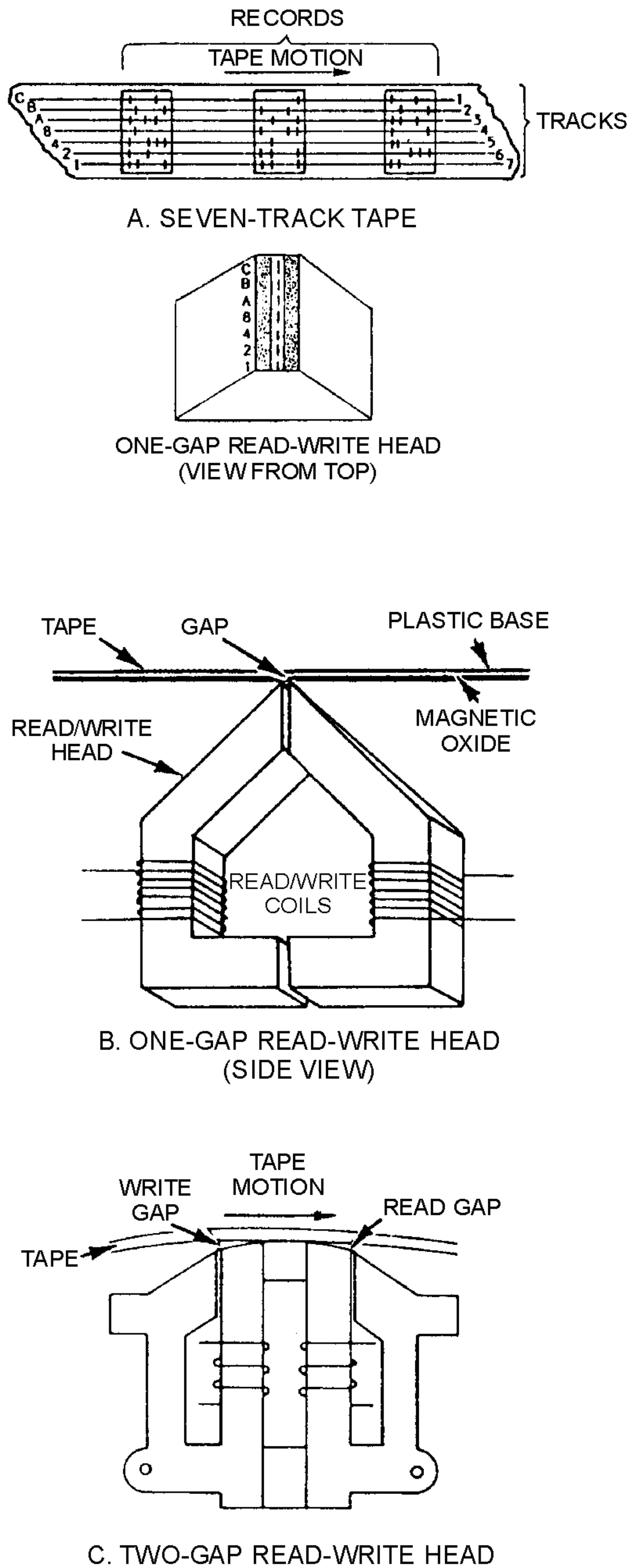

Figure 2-19.—Read/write head assemblies.

The major differences between magnetic tape units are the speed at which the tape is moved past the read/write head and the density of the recorded information. You know that density describes the number of binary digits, bytes, or frames we can record on an inch of tape. The most common tape densities are 800 and 1,600 BPI (or FPI). Tape speed (or tape movement) varies to a great extent, from less than 50 inches per second to more than 100 inches per second. How fast a tape unit reads and writes is specified as the character transfer rate which is calculated by multiplying the speed of the magnetic tape unit by the character density.

MAGNETIC DISK DRIVE UNITS (INPUT/OUTPUT)

Magnetic disk drive units are storage devices that read and write information on the magnetized surfaces of rotating disks (fig. 2-20). The disks are made of thin metal, coated on each side so that data can be recorded in the form of magnetized spots. As the disks spin around like music records, characters can be stored on them or retrieved in a direct manner. This direct accessing of data has a big advantage over the sequential accessing of data. It gives us fast, immediate access to specific data without having to examine each and every record from the beginning. You can direct the disk drive to begin reading at any point. This is like the phonograph record, you can place the needle at any point and begin playing at any point.

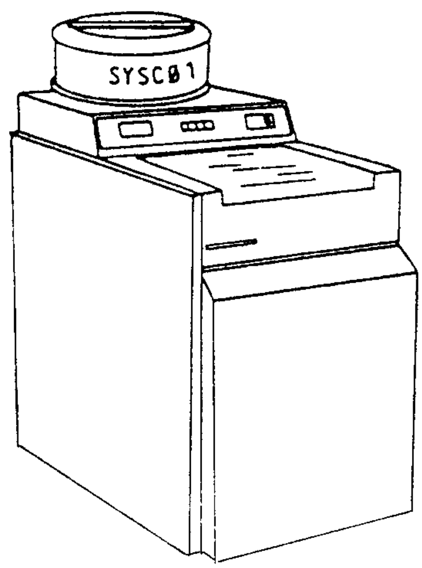

Figure 2-20.—Magnetic disk drive unit.

Located within each disk drive unit is a drive motor that rotates the disk at a constant speed, normally 3,600 revolutions per minute (rpm); or, if you prefer, 60 revolutions per second. The rotational speed for floppy disks is usually between 300 and 400 rpm because of their plastic base. Data is written on the tracks of a spinning disk surface and read from the surface by one or more (multiple) read/write heads. When reading from and writing to hard disks (rigid disks), the read/write heads float on a cushion of air and do not actually touch the surface of the disk. The distance between the head and the surface varies from a millionth of an inch to one-half millionth of an inch. This distance is called the flying height. When multiple disks (platters) are packaged together as a unit in a disk pack, a number of access arms and read/write heads are used to access both surfaces of each platter (fig. 2-21). The disk pack shown consists of six metal disks mounted on a central spindle. Data can be recorded on all surfaces except the top surface of the top disk, and the bottom surface of the bottom disk. These two surfaces are intentionally left blank for protection.

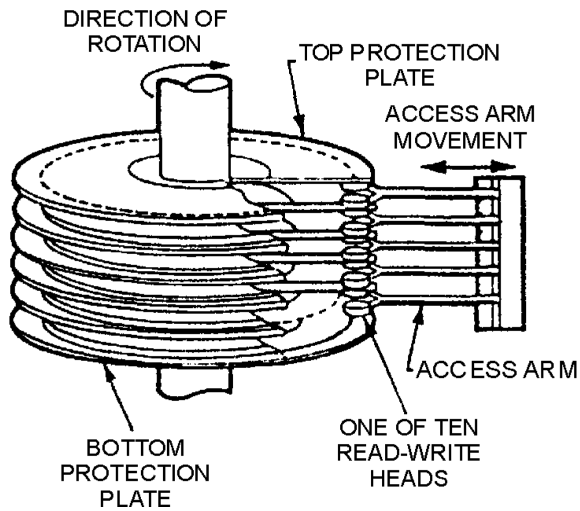

Figure 2-21.—Multiple access arms, read/write heads used with disk packs.

FLOPPY DISK DRIVE UNITS (INPUT/OUTPUT)

Floppy disk drive units are physically smaller than magnetic disk drive units and are typically used with personal (desktop) computers (fig. 2-22). The unit consists of a disk drive in which the disk rotates and a controller containing the electronic circuitry that feeds signals onto and from the disk. The disk (diskette) is a thin, flexible platter (floppy disk) coated with magnetic material so characters can be recorded on the surface in the form of magnetized spots. Floppy disks come in several sizes from 3 to 8 inches in diameter. The most common are the 8-inch disk, the 5 1/4-inch disk, and the 3 1/2-inch disk.

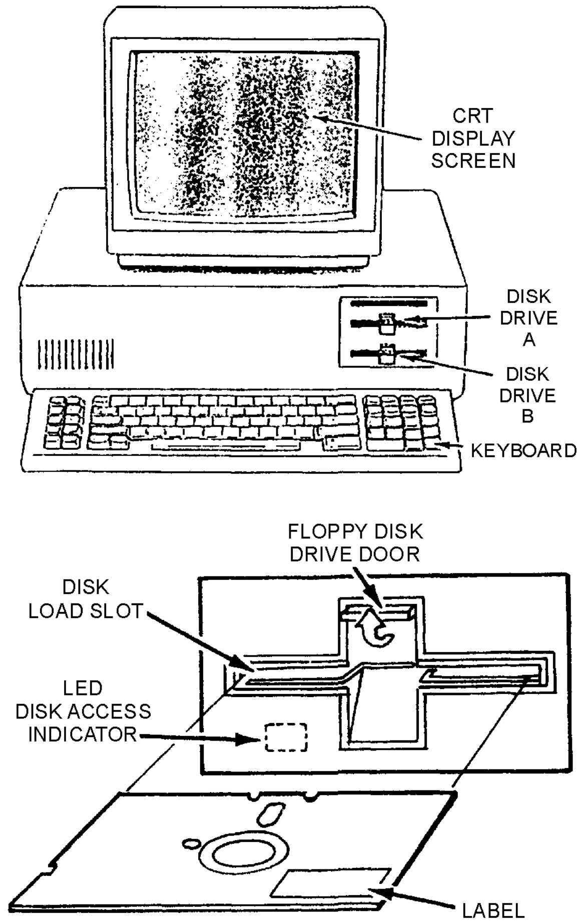

Figure 2-22.—Floppy disk drive unit.

PRINTERS (OUTPUT)

Printers are widely used output devices that express coded characters on hard (paper document) copy (fig. 2-23). They print out computer program results as numbers, letters, words, symbols, graphics, or drawings. Printers range from electronic typewriters to high-speed printers. High-speed printers are usually used on mainframes and minis to prepare supply requisitions, pay checks, inventory, or financial reports at 10 lines per second and faster. The types of printers we'll discuss are daisy-wheel, dot matrix, ink jet, and laser. These are the ones commonly used with personal computers.

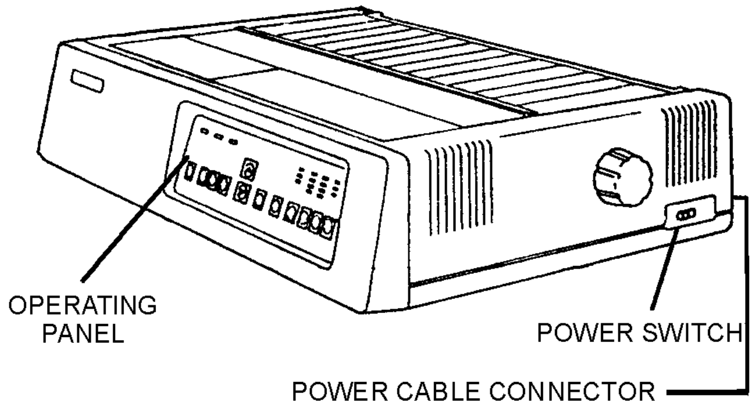

Figure 2-23.—Printer.

Daisy-Wheel Printers

Daisy-wheel printers have the most professional-looking, pleasing-to-the-eye print of all the printers in the character-at-a-time impact printer class. Daisy-wheel printers are often used in an office or word processing environment, where crisp, sharp, high-quality (letter quality) characters are a must. The daisy-wheel printer uses a round disk, with embossed characters located at the end of each petal-like projection (one character per petal), similar to the petals of a daisy, as shown in figure 2-24. A drive motor spins the wheel at a high rate of speed. When the desired character spins to the correct position, the print hammer strikes that character causing it to be printed on the paper. Once printed, the daisy wheel continues to move, searching out the next character to be printed, until the line is completed. The speeds of daisy-wheel printers range from 30 to 60 characters per second (cps).

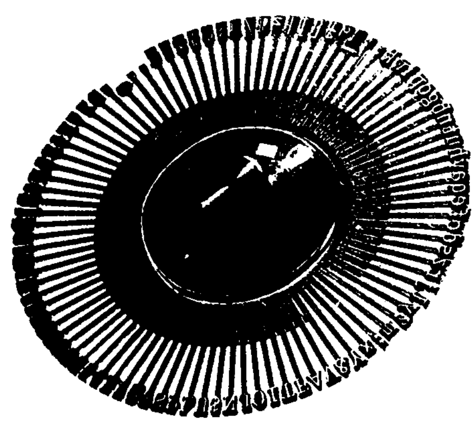

Figure 2-24.—A daisy-wheel print wheel.

Dot-Matrix Printers

Dot-matrix printers, (also known as the wire matrix printers) create characters in much the same way you see numbers on the scoreboard at a baseball or football game. In contrast to the daisy-wheel printers, dot-matrix printers use an arrangement of tiny pins or hammers, called a dot matrix, to generate characters a dot-at-a-time. A dot-matrix print head builds characters out of the dots created by the pins in the matrix. Figure 2-25, view A, shows what dot matrix characters look like when printed.

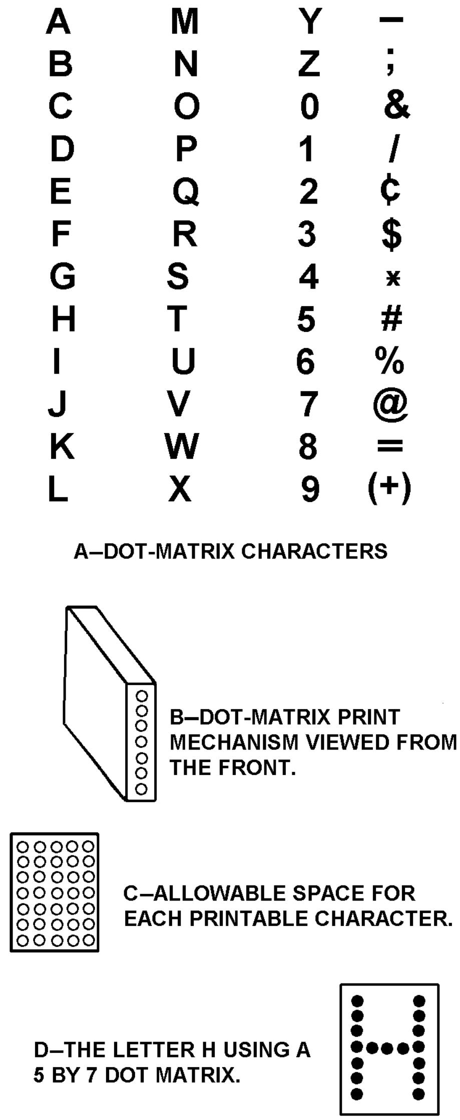

Figure 2-25.—Dot-matrix printing.

The dot matrix is defined in terms of rows and columns of dots. A 5 by 7 matrix uses up to five vertical columns of seven dots to create a character. An example of a 5 by 7 matrix printing the letter H is shown in figure 2-25, view D. The size of dot matrixes varies from a 5 by 7 matrix to as large as a 58 by 18 matrix. A number of dot-matrix printers use a single vertical column of pins to print characters, as shown in figure 2-25, view B. The characters are printed by moving (stepping) the print head a small amount and printing the vertical columns one at a time until the character is printed as shown in figure 2-25, views C and D.

The size of the matrix determines the quality of the printed character. In other words, the more dots used to print a character, the better the character is filled in and the higher its print quality. Dot-matrix printers are faster than the daisy-wheel printers with speeds ranging from 60 to 350 cps, but their print quality is not as good.

Ink Jet Printers

Ink jet printers employ a technique very similar to the way we use a can of spray paint and a stencil. A spray of electrically charged ink is shot (under pressure) toward the paper. Before reaching the paper, the ink is passed through an electrical field which forms the letters in a matrix form. The print resulting from this process consists of easy to read, high-quality characters. Some manufacturers use large droplets of ink for faster printing, while others use small droplets for better clarity but with slightly reduced printing speeds. These printers can print up to 300 cps (characters per second).

Laser Printers

Laser printers direct a beam of light through a rotating disk containing the full range of print characters. The appropriate character image is directed onto photographic paper, which is then put through a toner, developed, and used to make additional copies. The print resulting from this process consists of sharp, clean images that are easy on the eyes. These printers can print up to 20,000 plus lines per minute, or 26,666 cps (characters per second).

KEYBOARDS (INPUT)

A keyboard is nothing more than an array of switches called keyswitches. Keyboards are designed to input a code to the computer when a keyswitch is depressed. Each keyswitch, or key, on the keyboard is assigned a particular code value; and it is usually imprinted with a legend to identify its function. Figure 2-26 shows a keyboard combined with a crt on a microcomputer.

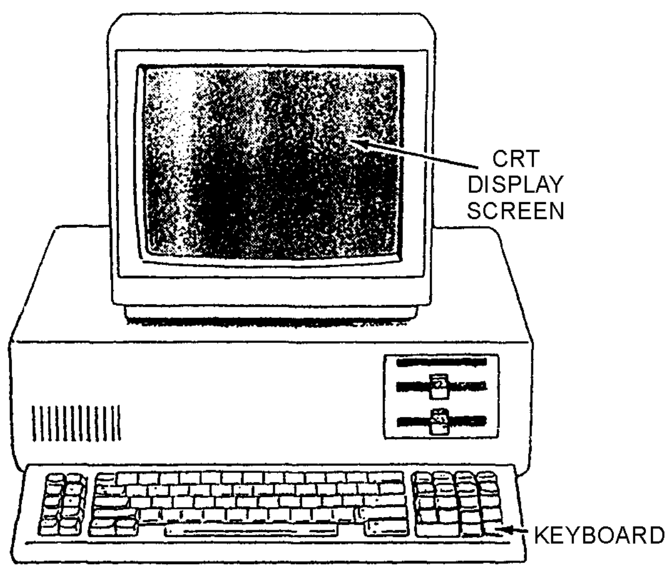

Figure 2-26.—Keyboard combined with a crt and microcomputer.

The primary purpose of a keyboard is to enter or input alphanumeric (numbers, letters, and special characters) character codes. The major grouping of keyswitches on a keyboard will be in one of the two styles of a typewriter keyboard arrangement (QWERTY or DVORAK). The typewriter keyswitches are arranged in 4 rows of 10 or more switches. The keyboard arrangement shown in figure 2-27 is QWERTY. The rows are usually offset to the row above to make it easier to reach all the keys when typing. The tops of the individual keyswitches are sculptured to conform to the shape of the human finger.

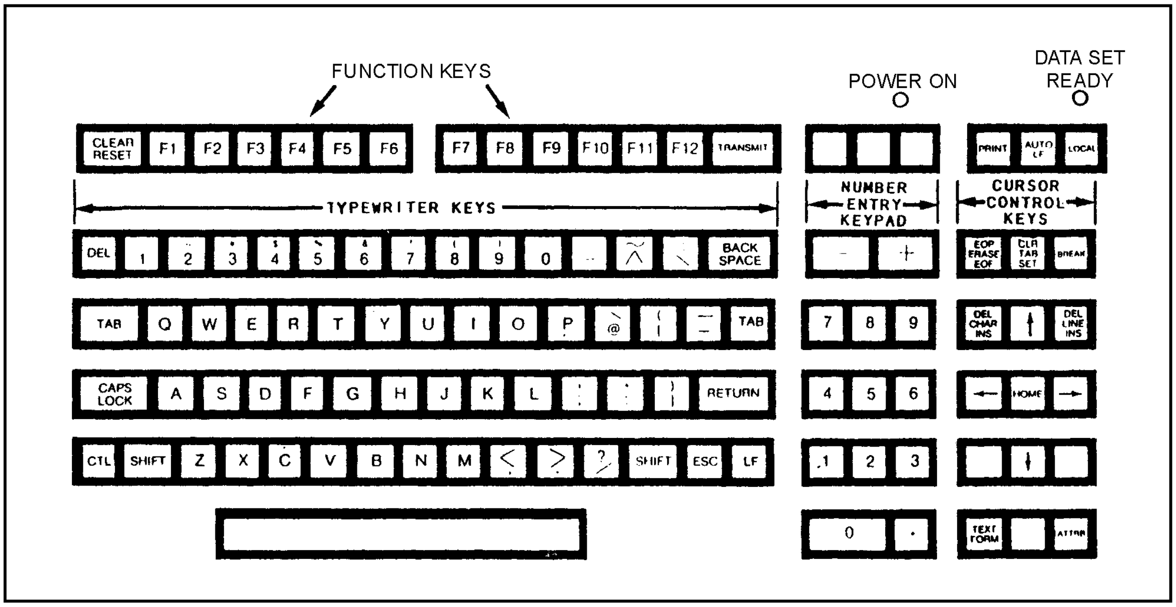

Figure 2-27.—Keyboard layout.

Other groupings of keyswitches are used for special purposes, such as number entry (calculator) keypads, special function switches (F1-F12), and cursor control keys. The special function switches allow an operator to use the special functions designed in the software. For example, in a word processing program, you can use them to spell check a document, search for a particular portion of text, move text from one place to another, and to print hard copies of a document. These are but a few of the functions allowed; however, as you become more familiar with computers you will learn them all. The cursor control key allows you to move to different locations on the screen.

The design of keyboards varies from device to device and is dependent on the requirements of the system in which the keyboards are installed.

Keyboards are generally used with nontactical computer systems. However, the newer tactical display system consoles have optional keyboards for data entry. A keyboard may be built into the display device, or it may be a separate component connected only by a communication cable.

DISPLAY DEVICES

Display devices are the crts and other displays that are part of computer terminals, computer consoles, and microcomputers. They are designed to project, show, exhibit, or display softcopy information (alphanumerics or graphic symbology).

The information displayed on a display device screen is not permanent. That is where the term soft-copy comes from. The information is available for viewing only as long as it is on the display screen. Two types of display devices used with personal/microcomputers are the raster scan crt's and the flat panel displays.

Raster Scan Crts

Raster scan crts (tv scan video monitors or display monitors) are used extensively in the display of alphanumeric data and graphics. They are used primarily in nontactical display applications such as SNAP II user terminals and desktop computers.

The raster is a series of horizontal lines crossing the face of the crt screen (fig. 2-28). Each horizontal line is made up of one trace of the electron beam from left to right. The raster starts at the top left corner of the crt screen. As each horizontal line is completed, the blanked electron beam is rapidly returned or retraced to the left of the screen.

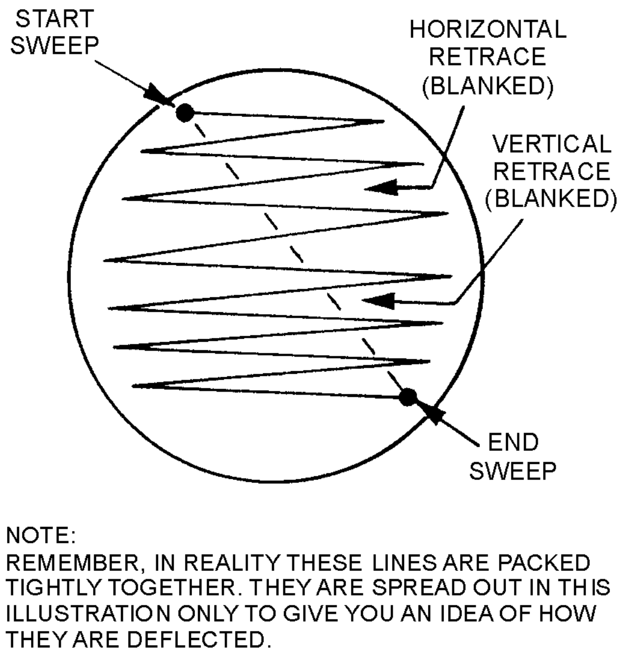

Figure 2-28.—Raster or TV scan.

Vertical deflection moves the beam down, and the horizontal sweep repeats. When the vertical sweep reaches the bottom line of the raster, a vertical blanked retrace returns the sweep to the starting position of the raster, and the process is repeated.

Each completed raster scan is referred to as a field; two fields make up a frame. The display rate of fields and frames determines the amount of flicker in the display that is perceived by the human eye. Each field is made up of approximately 525 horizontal lines. The actual number of horizontal lines varies from device to device. A frame consists of the interlaced lines of two fields. The horizontal lines of the two fields are interlaced to smooth out the display. A display rate of 30 frames per second produces a smooth, flicker-free raster and corresponding display on the screen.

PICTURE ELEMENTS.—The actual display of data results from the use of picture elements. A picture element is a variable dot of light derived from video signals input to the display monitor. The picture elements, often called pixels or pels, are contained in the horizontal scan lines crossing the face of the crt screen. The horizontal and vertical sweeps are continuous and repetitive in nature.

Pictures with alphanumeric characters and graphics can be created and displayed by varying the intensity or brightness of the picture element dots. This is done in conjunction with the phosphor coating on the face of the crt.

The number of picture elements in each horizontal line varies from device to device. The actual number of picture elements is dependent on the frequency bandwidth of the video monitor, the number of characters to be displayed on a line, and the physical size of the screen.

Each picture element is addressable by a row and column address. Picture elements are numbered from left to right on each horizontal line (column number). Each horizontal line has a row number. Picture elements, at a minimum, will have off (blanked) or on (full intensity) states. Many display devices have the capability to display picture elements at varying degrees of intensity for the display of graphics.

Characters are assembled on the screen in much the same way as a dot-matrix print head prints a character. It takes several horizontal lines and picture elements on each line to create a character. Figure 2-29 shows the generation of the character A, 7 picture elements wide and 9 horizontal lines high. The character is built using what is, in effect, a 7 by 9 dot matrix. The picture elements used to build the character would be at full intensity; the remaining picture elements in the matrix would be blanked. If dark characters on a lighted screen were desired, then the character picture elements would be blanked and the remainder displayed at full intensity.

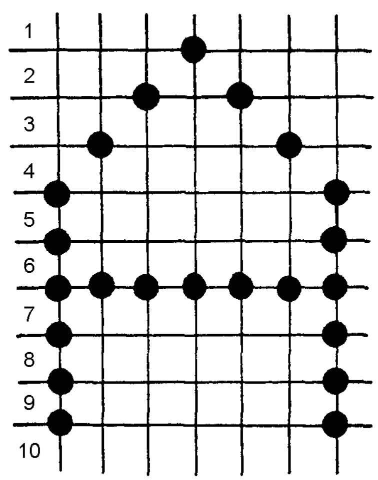

Figure 2-29.—A 7 by 9 picture element character.

Approximately 640 picture elements per horizontal line are required for the display of an 80 character line. Therefore, you can expect 140,000 picture elements on a raster scan display screen (80 alphanumeric characters per line and 25 lines).

HORIZONTAL AND VERTICAL RESOLUTION.—Horizontal resolution is defined in terms of the number of picture elements that can be displayed on the horizontal line without overlapping or running into each other. It is often stated in terms of lines of resolution. In other words, a monitor with a horizontal resolution of 1,000 lines can display 1,000 vertical lines using 1,000 picture elements per line.

Vertical resolution depends on the number of horizontal scan lines used by the particular display raster. Generally, the greater the number of scan lines, the easier it is to resolve a horizontal line of display. This characteristic remains true up to a point, called the merge point, where the variation between the lines cannot be detected by the human eye.

DISPLAYING DATA ON RASTER SCAN SCREENS.—Raster scan displays are repetitive in nature. The raster frame is displayed approximately 30 times a second.

The basic video monitor does nothing more than display the video signals it receives. If no video signals are received, then all the picture elements remain blanked, and the screen is blank in each frame. For data to be displayed accurately, each and every frame must blank and unblank the same picture elements.

The digital logic that drives video monitors is designed to take advantage of the repetitive nature of frames. There can only be a fixed number of picture elements on the screen of a display; therefore, the contents of the display screen are organized into a data unit called a page.

The page contains the status of every picture element on the display screen. The page is usually stored in some form of random-access memory, RAM chips being the most common. The contents of page memory, or, as it is sometimes called, video memory, are continually scanned by the video generation logic and used to develop the video signals for the picture element display. The picture element locations in page memory are read in time to develop the video signals for the picture element display on the horizontal lines.

If the display is to be changed, the contents of page memory must be changed. The display on the screen changes as new data is stored in page memory. Two addressing methods are used with page memory.

Unformatted Displays.—Displays that reference page memory by picture element address are called unformatted or fully populated displays. These displays are more commonly used for graphics rather than alphanumeric characters.

Formatted Displays.—Often displays are organized by character position and line number. These displays are known as formatted displays. This display method is used with devices displaying alphanumeric characters only or those with an alternate graphic capability.

The video generation logic of these types of displays scans the entire page memory, as before, to generate the display picture elements. The difference is in the way the new data is written into the page memory. Individual picture element addresses are not used. Character addresses are used to reference page memory.

The screen is organized into character lines. Each line is made up of a fixed number of character positions or columns. A fixed number of character lines can be displayed. A common arrangement found on display screens is twenty five 80-character lines, or 2,000 characters.

The character set that can be displayed on a device's formatted screen is stored in ROMs or PROMS. That is, the dot-matrix (picture element) patterns for each individual character to be displayed are stored. Different character sets may be displayed by simply replacing the appropriate ROM or PROM chips with new chips containing different character patterns.

Upon receipt of a character code and a row and column address, the device logic reads the picture element pattern (dot matrix) from the ROM and writes the pattern into the appropriate character position in the page memory. The desired character is then displayed at the correct position. Other display devices store the codes in page memory and convert the codes to picture element dots when scanning memory to refresh or redisplay the characters on the screen. The use of formatted displays greatly simplifies the programming requirements for the display of alphanumeric data.

Flat Panel Displays

A number of display methods are in use that are designed to reduce the depth of the crt display caused by the length of the tube. These devices are collectively known as flat panel displays. Three types of flat panel displays commonly in use with computer systems are liquid crystal displays (LCDs), gas plasma displays (GPDs), and electroluminescent displays (ELDs).

The screens of these flat panel displays are made up of pairs of electrodes. Each pair of electrodes is used to generate one picture element.

The liquid crystal display differs from the gas plasma and electroluminescent displays in that it does not generate its own light for the picture elements. The LCD requires an external light source, often called a backlight, for computer applications. The liquid crystal material between the charged electrodes becomes translucent when voltage is applied and allows the backlight to shine through as a picture element.

In the gas plasma and electroluminescent displays, the picture element light is generated by ionizing a gas (neon or neon argon) between the charged electrodes (gas plasma display) or by stimulating a luminescent material in the same manner (electroluminescent display). In either case, the picture element only emits light when the electrodes have voltage applied to them.

One of the advantages of flat panel displays is that smaller voltages are required for their operation than for a crt. Gas plasma displays use approximately 200 volts to charge the electrodes, and electroluminescent displays require only 20 volts.

The picture elements in these displays are addressed by the row and column method. Displays with as many as 737,280 picture elements (960 rows by 768 columns) have been developed.

The picture elements on flat panel displays are not lighted continually. This would require a large amount of power and generate excessive heat. A sequential scan similar to a crt raster is used. Once again a page memory is required. The picture element electrodes are on and off as the scan sequentially addresses page memory.

Those picture elements that are to display a dot are momentarily turned on and off starting with the first picture element in the top row, or line, and ending with the last picture element on the bottom row. The picture elements are turned on and off at a high enough frequency that the human eye cannot detect the flicker of the off-on-off cycle.

The sequential scan used to light the picture elements is continuous and repetitive. Once again, the page memory must be changed to change the display. Flat panel displays may be formatted or unformatted in the same manner as crt displays.

Q-35. What is the purpose of any magnetic tape unit?

Q-36. What are the major differences between magnetic tape units?

Q-37. Why is direct accessing of data a big advantage over the sequential accessing of data?

Q-38. What is a floppy disk?

Q-39. What are the three most common sizes of floppy disks?

Q-40. What output device expresses coded characters as hard copy (paper documents)?

Q-41. What four types of printers are commonly used with personal computers?

Q-42. What is the primary purpose of a keyboard?

Q-43. Raster scan or tv scan video monitors are used extensively for what purpose?

Q-44. How many fields make up a frame?

Q-45. A field is approximately how many horizontal lines?

Q-46. What are picture elements often called?

Q-47. Vertical resolution depends on what?

Q-48. Flat panel displays are designed to reduce what problem of a crt display?

Q-49. What does the liquid crystal display require for computer applications?

SUMMARY

Now that you have finished chapter 2, you should be feeling more at ease with digital computers. You should realize by now that they are not so hard to understand, once you have the terminology down. The information that follows summarizes the important points of this chapter.

The **CENTRAL PROCESSING UNIT** is the brain of the computer. We generally refer to it as the cpu or mainframe.

The **CONTROL SECTION** directs the flow of traffic (operations) and data, and maintains order within the computer.

The **ARITHMETIC-LOGIC SECTION** performs all arithmetic operations-adding, subtracting, multiplying, and dividing. It also tests various conditions during processing and takes action based on the result.

INTERNAL STORAGE is sometimes referred to as primary storage, main storage, or main memory (because its functions are similar to our own human memory). It stores the programs and data.

MAGNETIC CORE STORAGE is made up of tiny doughnut-shaped rings made of ferrite (iron) that are strung on a grid of very thin wires.

SEMICONDUCTOR STORAGE consists of hundreds of thousands of tiny electronic circuits etched on a silicon chip.

BUBBLE STORAGE is made of semiconductor material in the form of a very thin crystal.

READ-ONLY MEMORY (ROM) allows us to permanently store programs that will not be lost even when the computer is powered down.

RANDOM-ACCESS MEMORY (RAM) is read/ write memory. It is the working memory, rather like a blackboard, that you can scribble down notes, read them, and rub them out when you are finished with them.

SECONDARY STORAGE is the memory outside the main body of the computer (cpu) where we store programs and data for future use.

MAGNETIC TAPE is a sequential access storage device.

MAGNETIC DISK is a direct access storage device.

INPUT/OUTPUT DEVICES are the means by which the computer communicates with the outside world. These include magnetic tape units, magnetic disk drive units, floppy disk drive units, printers (daisy-wheel, dot-matrix, ink jet, and laser), and display devices (raster scan crt and flat panel).

ANSWERS TO QUESTIONS Q1. AND Q49.

A-1. *The central processing unit.*

A-2. *Three.*

A-3. *Control section, internal storage section, and arithmetic-logic section.*

A-4. *A telephone exchange.*

A-5. *Transfer, arithmetic, logic, and control.*

A-6. *Logic.*

A-7. *Internal storage.*

A-8. *Loading.*

A-9. *Tiny doughnut-shaped rings made of ferrite iron.*

A-10. *Hundreds of thousands of tiny electronic circuits etched on a silicon chip.*

A-11. *Integrated circuits.*

A-12. *All data in memory is lost when the power source is removed.*

A-13. *Nonvolatile (magnetic core storage and bubble memory are examples).*

A-14. *A very thin crystal made of semiconductor material.*

A-15. *By passing a current through a control circuit imprinted on top of the crystal.*

A-16. *The data is still present after being read.*

A-17. *Read-only memory (ROM).*

A-18. *Only the manufacturer.*

A-19. *No.*

A-20. *Read/write memory.*

A-21. *By giving the computer the address of the location where the data is stored or is to be stored.*

A-22. *Already programmed by the manufacturer or in a blank state.*

A-23. *If a mistake is made and entered, it cannot be corrected or erased.*

A-24. *Erasable programmable read-only memory.*

A-25. *With a burst of ultra-violet light.*

A-26. *Largely because of their direct access capabilities.*

A-27. *In a number of invisible concentric circles called tracks.*

A-28. *A disk address.*

A-29. By the bits per inch of track and the tracks per inch of surface.

A-30. By cylinder or sector.

A-31. Recording density.

A-32. The usable recording (reading/writing) surface or usable storage area.

A-33. The tracks in which the data is stored are assigned to channels that form circular bands around the drum.

A-34. Sectors.

A-35. To write data on or read data from a magnetic tape.

A-36. The speed at which the tape is moved past the read/write head and the density of the recorded information.

A-37. It gives us fast, immediate access to specific data without having to examine each and every record from the beginning.

A-38. A thin, flexible platter coated with magnetic material so characters can be recorded.

A-39. 8 inch, 5 1/4 inch, and 3 1/2 inch.

A-40. Printers.

A-41. Daisy-wheel, dot-matrix, ink jet, and laser.

A-42. To enter or input alphanumeric character codes.

A-43. The display of alphanumeric data and graphics.

A-44. Two.

A-45. 525.

A-46. Pixels or pels.

A-47. The number of horizontal scan lines used.

A-48. Reduce the depth of the crt display caused by the length of the tube.

A-49. An external light source, called a backlight.